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THE ELIMINATION OF BACKGROUND "NOISE" IN SENSITIVE PULSE AMPLIFIERS

By L. F. Curtiss

ABSTRACT

A study has been made of the problem of reducing the background "noise" in a high-gain resistance-capacity coupled pulse amplifier used for registering ionization of individual ionizing particles. It has been found that, even after due care has been taken to reduce disturbances in the first two stages, a great improvement can be effected by suitable modification of the final or output stage. This consists in using several output tubes, preferably pentodes, in parallel, and selecting an operating point on the characteristic curve such that small fluctuations in the voltage applied to the control grids produce practically no change in the plate current and yet all pulses which exceed these fluctuations in the desired direction are reproduced in the plate current. Although this arrangement involves some distortion of very small pulses, the gain in the legibility of the oscillograph record is sufficient to compensate for this slight disadvantage. The results obtainable under various conditions are illustrated by reproductions of oscillograph records.

CONTENTS

I. INTRODUCTION

Vacuum tube amplifiers, capable of registering directly the current pulses produced in shallow ionization chambers when separate α or H particles pass through, are limited in degree of amplification by background fluctuations or "noise." This noise becomes more troublesome as the amplification is increased until a state is reached where it may even mask entirely the current pulses from the ionization chamber. It may arise from a variety of causes, such as absorption of charge in the insulators of the ionization chamber, variations in electron emission from filaments of vacuum tubes, Johnson effect in resistors, and mechanical vibration of parts of the amplifier. All these causes can be dealt with more or less effectively by proper attention to the factors involved. However, noise is usually present to an annoying degree in all amplifiers which are capable of registering the ionization pulses of swift H particles arising from atomic disintegration.

In dealing with this problem it has been customary to give particular attention to the first stages of the amplifier, since any disturbance generated here is amplified in later stages. While investigating the possibilities of reducing the effects of this noise, the writer found that a considerable improvement could be effected by a simple modification of the output stage. This additional control is practicable because of the peculiar nature of a pulse amplifier used to amplify a unidirectional pulse.

II. MODIFICATION OF OUTPUT STAGE

The change from usual practice which has been found effective consists in using two or more tubes in parallel in the output stage and selecting an operating point on the grid voltage-plate current characteristic such that small fluctuations are suppressed without seriously distorting the pulse. This is only possible when the usual precautions have been taken to have the amplifier reasonably free from noise. It is necessary that the smallest pulses to be recorded be definitely larger than the background fluctuations. Under these conditions it is possible to suppress the noise almost entirely without greatly reducing the amplitude of pulses which may be only twice as large as the noise fluctuations. This makes the oscillograph record much easier to read and interpret since even the small pulses stand out sharply. Under the usual conditions it is often difficult to pick these out with certainty from the background disturbance.

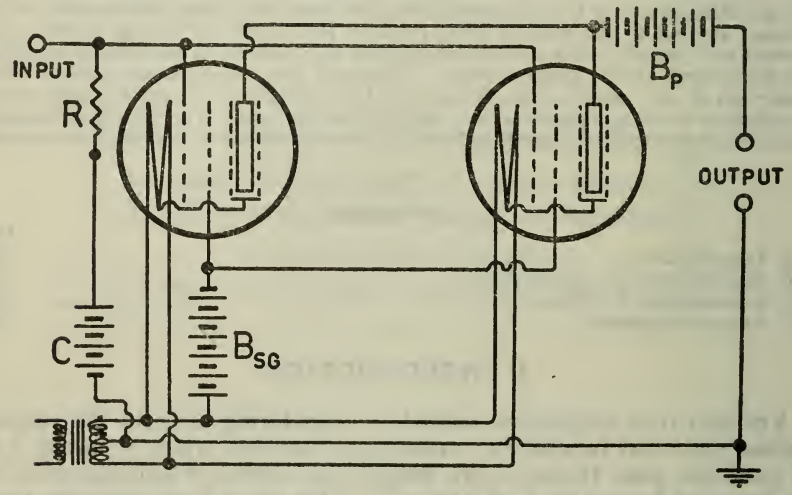

FIGURE 1.—*Diagram of connections showing two pentodes in parallel*
R=0.5 megohm, C=22½ volts, B_{SG}=175 volts, B_P=250 volts

In this method of suppressing noise it is essential that the output stage should receive a positive impulse from the preceding stage when a pulse comes through. It is also desirable to use two or more pentodes in parallel in the output stage as shown in Figure 1. It is then possible to select a bias of such value that the tubes are normally at a point on their characteristic where the curve is practically horizontal but such that a slight shift of the grid potential in the positive direction will cause an increase in the plate current. If the noise fluctuations are not sufficient to raise the potential of the grid above this critical potential, they will not appear in the plate current.

A clearer understanding of how this is possible may be obtained by reference to Figure 2, which is an actual grid voltage-plate current characteristic for two pentodes in parallel. The part of the characteristic below a grid potential of about −15 volts is nearly horizontal but above this potential it rises rapidly to the linear part of the curve. It can be seen at once that, if the incoming signals applied to the grid

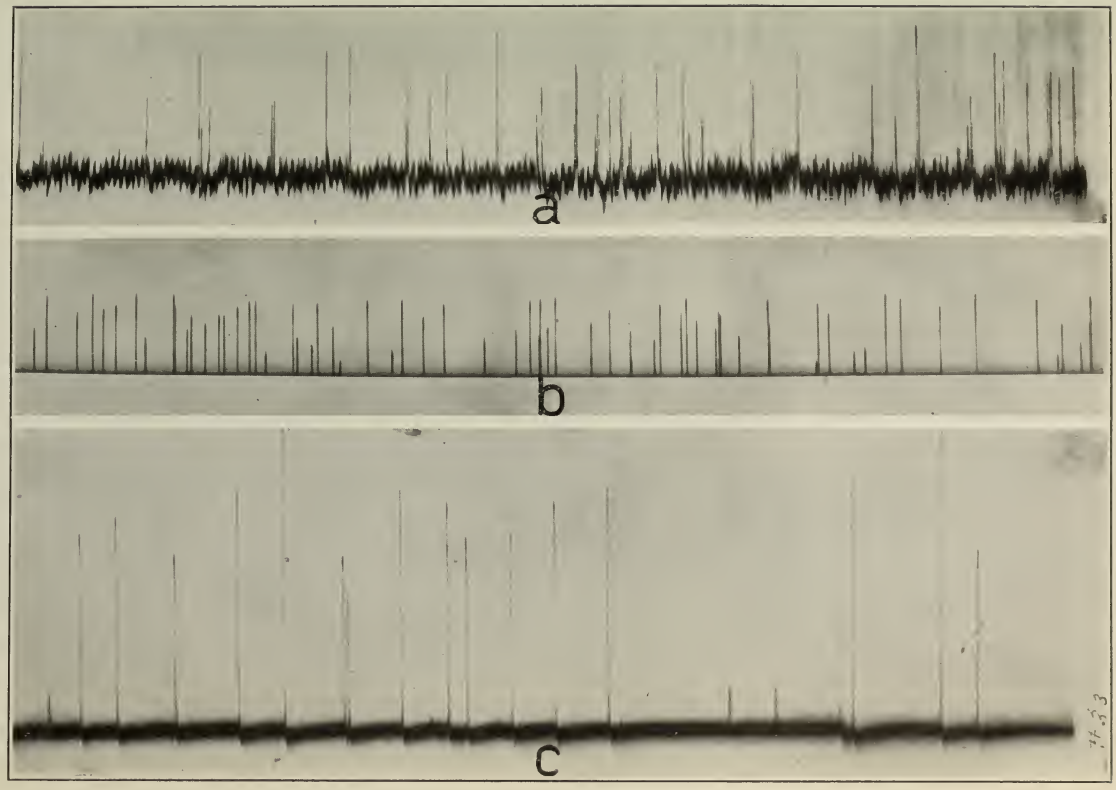

FIGURE 3.—*Oscillograph records*

a, Record obtained with usual output stage of one pentode biased to a steady plate current of 20 milliamperes; b, record with modified output stage; and c, record with modified output stage and a stepdown output transformer.

of these tubes are made up of a pulse S and a background noise represented by B in order of magnitude (this represents about the ratio of the pulse produced by very swift α-particles to the noise in a sensitive amplifier) and the steady grid bias is chosen at about -17 volts, the background will fail to produce any noticeable effect on the plate current, while the signal will be reproduced with only slight distortion. Even for the case of a disintegration proton, which would give a pulse approximately one-eighth of S, the distortion is not sufficient to render its detection difficult. When more accurate measurement is required, the correction for this distortion can be determined experimentally for a given amplifier.

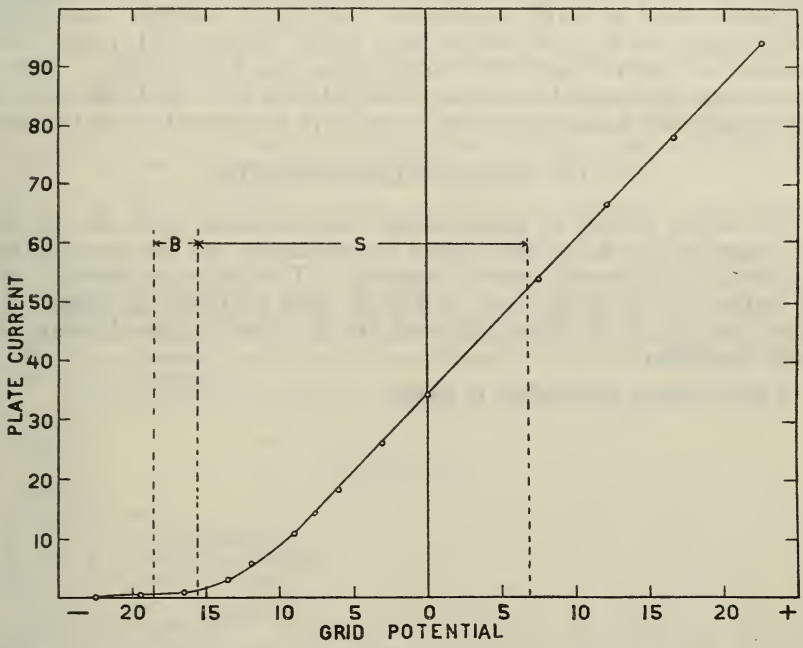

FIGURE 2.—*Grid voltage-plate current characteristic for two pentodes in parallel*

III. ADVANTAGES OF METHOD

The advantages of this modification of the output stage can be shown most readily by a comparison of oscillograph records obtained under various conditions. In Figure 3 a record is shown at (*a*), obtained with a single pentode biased to give a steady plate current of about 20 milliamperes. It is connected in the output stage of a 5-stage amplifier described elsewhere.[1] In this record the pulses due to α-particles are readily distinguishable, but it is almost impossible to identify and separate those due to protons from the background. At (*b*) is shown a record obtained with the same adjustment of the amplifier but using the modified output stage described above. This record shows that the noise has been suppressed entirely, resulting in a considerable gain in legibility.

[1] B. S. Jour. Research, vol. 9 (RP461), p. 115, 1932.

Records (*a*) and (*b*) were obtained by connecting a low-resistance bifilar oscillograph directly into the plate circuit of the output stage. This arrangement is very inefficient, since the optimum load resistance of a pentode is about 7,000 ohms. The situation calls for the use of an output transformer, but such a transformer would be of no use when supplied with an input current such as is shown at (*a*). However, using the modified arrangement and an output transformer of relatively low ratio (4:1), the record shown at (*c*) was obtained. In this, the peaks for all slow α-particles go entirely out of the picture. Those whose tops are visible represent either swift α-particles, extending more than halfway across the record, or protons. The pulses produced by the protons are roughtly one-fifth the amplitude of those caused by swift α-particles. Although a slight amount of disturbance due to noise can be seen in the background, it has been reduced to a point where all genuine pulses stand out clearly. Where circumstances demand, a transformer ratio of 16:1 could be used to advantage with a corresponding increase in the size of the deflections

IV. ACKNOWLEDGMENTS

The writer wishes to acknowledge the assistance of B. W. Brown for considerable help with these experiments and in making the numerous oscillograph records required. The polonium source used in testing the amplifier was obtained from material furnished the writer by Dr. C. F. Burnham and Dr. F. West, of the Howard A. Kelly Hospital.

Washington, December 1, 1932.